Effects of Mass Anomalies on the Rotation and State of Stress in Europa's Icy Crust

Paul O. Hayne
Department of Geophysics
Stanford University
397 Panama Mall, Stanford, CA 94305-2215
USA
phayne@stanford.edu

Norman H. Sleep
Department of Geophysics
Stanford University
USA

Jack J. Lissauer
Space Sciences Division
NASA-Ames Research Center
USA

Various sources of crustal stress have been proposed to explain the complex tectonic features observed on the icy surface of Europa. Tidal stresses vary on a diurnal time scale, while non-synchronous rotation (NSR) has been invoked as a source of cumulative stress with a period $>10^4$ years. The icy crust is likely decoupled from the rocky interior (i.e. by a liquid water ocean) so that only permanent deformations in the crust will affect observed rotation. In order for NSR to be viable, mass asymmetries in the crust must be small so that tidal torques dominate. However, data from Galileo reveal significant topographic relief (up to 1km), as well as long-wavelength features. Thus, torques due to variations in ice thickness may be large enough to affect Europa's rotation.

We examine the rotational and stress effects of mass anomalies in the ice shell, and their consequences for shell thickness. The amplitude and frequency of forced librations will depend on the size of the crustal mass anomaly. A large enough moment ratio will cause tidal lock and prevent NSR. Mass asymmetries are modeled by representing the gravitational potential in spherical harmonics, and calculating torques. A two-layer lithospheric model is then assumed in calculating stress due to isostatic compensation of topography. These stresses may contribute significantly to the global stress field. Additionally, the presence or absence of NSR may provide a constraint on the size of crustal mass anomalies, and thus constrain the ice shell thickness.